Drying of Curcuma (*Curcuma xanthorrhiza roxb*) Using Double Plate Collector Solar Dryer

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Abstract:

Curcuma (Curcuma xanthorrhiza roxb) currently used as traditional medicine and as a dye. If the Curcuma will be saved then the water content should not be more than 10-11%. The advantages of drying using a glass plate covered with double collector type can reduce the water content below 10-11 %, reduced drying time and produce dust-free product. The experiment is carried out by inserting curcuma that has been in the form of thin slices into the dryer. Dryers are equipped with several sensors those are (temperature, relative humidity, weight scale and the intensity of sun light) sensors. Measurements of those parameters are performed every interval of 5 minutes. The intensity of sunlight during the day it changes that followed by changes of relative humidity of air (RH) and the rate of water evaporation. Effect of RH, the intensity and temperature in the dryer to the drying characteristic is correlated using mathematical model. There are three common mathematical models used in this experiment as well as the Newton, Page's and Pabis and Page modified equation for calculate the (*Specific Moisture Evaporation Rate,* SMER) and dryer's performance is expressed by this parameter. The SMER on the 10^{th} of June 2012 reached 0,588 kg/KWh. From these data could be concluded that the effectiveness of the dryer is very good for use as a drying of agricultural products such as curcuma. The equation of this process is modification temperature page equation as MR = $\exp(0.004.T^{0.468}.t^{1.3615})$ with the RMSE was 2.2 %.

Keywords: agriculture product, mathematical modeling, renewable energy, solar drier.

1. Introduction

Curcuma is used as the source of a natural antibiotic that is widely used as traditional medicine. Some are used as natural dye for food. In order to be safe to be stored in a relatively long time, it is necessary to reduce moisture content to below 10%. Drying using direct solar dryer is very difficult to be able to reduce the moisture content up to 10% due to the relatively low temperature and slow evaporation of water. Double plate collector solar driers are designed to absorb maximum sunlight through the transparent glass plate mounted on the top of the dryer. Under the glass plate, there is black zinc plate to absorb the light being reflected by the plate glass. Absorption of light by a black plate causes the temperature inside the dryer increase. This causes the temperature inside the dryer is higher than the outside. This is the reason why a faster drying time of double plate collector dryer compared to conventional drying. Solar dryer with double plate glass collector is an indirect type natural air circulation. The excess sunlight will be absorbed or converted into heat energy, on a black plate (black body) and heat radiation from the black plate will be captured by two glass plates, so that the temperature is higher or better than the direct drying. When compared the single plate glass collector with the double plate glass collector, black body not loss more heat because the air is insulated between glass. Another advantages from this if the weather is uncertain (cloudy or rainy) the dried material does not need to be packed (stacked) but just left it in the drying chamber, and the drying process, is took place at night also. Because of that the drying will be faster than the traditional ones.

Air as a medium for absorbing moisture from the material, is inserted and removed periodically. When the temperature inside the dryer has not changed (constant), the air is removed and fresh air into the dryer. During the drying process, conditions (light intensity, temperature, and relative humidity and weight of the sample) in the dryer changed with time until at some point will be constant. Drying is complete when the weight of the material has been constant. The performance of solar dryers can be presented by Specific Moisture Evaporation Rate (SMER) **[1]**. This is defined as the ratio of amount of water that evaporates and energy for drying. SMER parameter is expressed in equation (1)

$$\mathrm{SMER} = \frac{\text{Amount of water that evaporates}}{\text{Energy for drying}} \left(\frac{\mathrm{kg}}{\mathrm{kWh}}\right) \quad (1)$$

2. Material and Methods

Mathematical model

The model is based on the relationship between weight of water that evaporates as a function of the condition in the dryer those are temperature and % RH of air. Reduction of water content of the material is calculated based on equation (2) (dry basis) and equation (3) (wet basis).

$$M = \frac{Gw - Gd}{Gd} \quad (2)$$

$$M = \frac{Gw - Gd}{Gw} \quad (3)$$

Mass of the evaporated water can be written using equation (4) **[2,3]**

$$MR = \frac{M_t}{M_0} \quad (4)$$

Basically the value of MR is influenced by temperature and time. As previously reported by several researchers. In this study MR parameters were determined using several models. Among them is the Henderson, Pabis and Page Model. The Constanta value in the model were determined by least squares **[3]**.

$$MR = \exp(-kT^n t) \quad (5)$$

$$MR = \exp(-kT^m t^n) \quad (6)$$

$$MR = \exp\ (\exp(-kT^m t) \quad (7)$$

$$MR = a\ exp\,(-kT^m t^n) \quad (8)$$

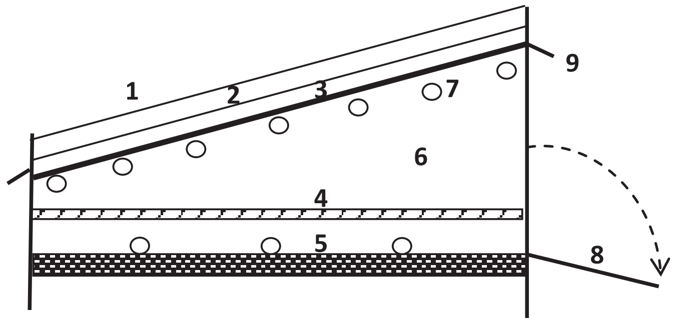
The above moisture ratio models a function of temperature, and influenced by other variables, its mean that the model is applicable to the varies drying conditions as well as the double plat collector dryer due to the drying chamber conditions those are air humidity and temperature are always changing so the above models did not need to be modified. The k constant is varied with temperature and air humidity **[4]**, and the temperature of the drying chamber depends on the collector temperature. The correlation between k constant and the process parameters present by the mathematical model that has been reported by many researches there are Newton equation model, Henderson-Pabis and Page and Page modified model as present in equation (5-8) below:

Models are selected based on the value of the parameter RMSE (Root Mean Square Error). RMSE values are calculated based on the square root of the difference in moisture content of experimental and model. RMSE is calculated using linear regression methods as written in equation (9). Appropriate model is the model that gives the smallest RMSE

$$RMSE = \left[\sqrt{\frac{1}{N}\sum_1^N (MR_{pre} - MR_{exp})^2}\ \right] \quad (9)$$

Experiment

Curcuma purchased from the market of Prambanan - Yogyakarta-Indonesia). Washed before being dried and sliced with a thickness of 2 mm and then immediately put in the dryer. A system of double plate collector dryers can be seen in Figure 1. Dryer system consisting of two glass plates are arranged with a distance of 5 cm. Under the glass plate is black zinc plate. The bottom of the dryer is coated with sand which is useful to isolate the heat. Above the sand layer there is a rack to put the sample. Dryers are equipped with air vents that can be opened and closed. Drying system equipped with a measuring instrument that is: piranometer (light intensity measuring instrument). Thermocouple for measuring temperature, RH meter to measure relative humidity and scales to measure the weight of the sample at any time.



Parts of the dryer system
1. First flat glass plate
2. Second flat glass plate
3. Black absorber
4. Material rack
5. Sand as isolator
6. Drying chamber
7. Vent
8. Entrance
9. Caping

Figure 1. Double plate collector solar dryer system

Two kg of curcuma were scattered on the drying rack. In addition to 50 grams of curcuma was placed on the scales to determine the amount of water evaporated for each time. Scales placed in the dryer and placed in a certain place so that we may easily read the weight of the sample. Measurement is done for every 5 minutes to the intensity of light, air relative humidity and temperature and sample weight. This is done until the value is not changed with time. Once the condition has not changed, the air valve is opened so that the saturated air is out and fresh air will enter. After that the air valve is closed and the drying is continued.

3. Result and Discussion.

The weight of the curcuma before drying the is 2.000 g and after drying is 7.73 g. The amount of water evaporated from the sample (W)is calculated using equation (10).

$$W = \frac{G_m}{Gs_0}(Gs_0 - Gs_t) = \frac{2000}{50}(50 - 7.73) = 1691.6\, g \tag{10}$$

Energy for drying (E_d) determine using equation . (11).

$$E_d = A\int_0^t Id_t = 2.8764\; kWh \tag{11}$$

From this data could to determine the performance for 2 kg of curcuma is, . $SMER = \frac{1{,}691{,}6}{2{,}876.4} = 0.5881\ \frac{kg}{kWh}$

Figure 2 shows the relationship between time and temperature of the material (Tm-t), black plate temperature (Tbb), intensity, MR (%) and weight of the sample (G). Light intensity at first rises until noon and at 12:00 o'clock reach the highest intensity. After 12 o'clock of nearly constant intensity and remained constant until 14:05 o'clock. After that the intensity down. The same pattern was seen in the Figure for a black plate temperature and the temperature of curcuma. This is consistent with the pattern of intensity, the higher the intensity of light, is higher energy is absorbed by the black plate and also the higher the temperature of the plate and curcuma temperature and vice versa. Data taken on 10 June 2012 at 10:50 West Indonesian Time (WIT) to 15:10 o'clock in the cloudy atmosphere. Black plate temperature varies between 80-92^{o}C and the curcuma temperature between 40-43^o C. Look at the curcuma temperature data only 43 C can be conclude that active component in curcuma will not be damaged. While the longer the drying time, the smaller the sample weight as well as moisture content (MR).

Constante value of the models obtained by fitting the data of experimental with the model using linear regression methods. The results of calculations shown in Table 1. Test the validity of the models is done using equation (9). A valid model of its smallest RMSE value. The smallest RMSE values obtained from equation (6) and (8) of 2.2% and 2%.

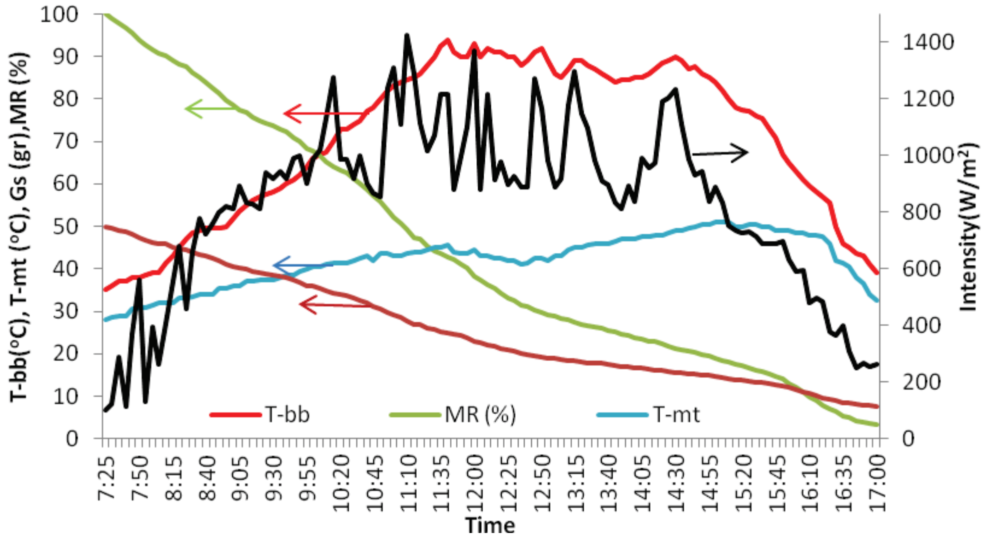


Figure 2. Data measurements are conducted on June 10, 2012.

Tabel 1.. Constant values of the evaluation results and the value of RMSE

No	M. Modelling	a	k	m	n	RMSE
1	$MR = \exp(-k.T^{m}.t)$	-	0.0028	0.0417	-	0.053038
2	$MR = \exp(-k.T^{m}.t^{n})$	-	0.0004	0.0468	1.3615	0.022226
3	$MR = a.\exp(-k.T^{m}.t)$	1.1075	0.0067	-0.1293	-	0.083187
4	$MR = a.\exp(-k.T^{m}.t^{n})$	1.0035	0.0008	-0.0713	1.3082	0.020833

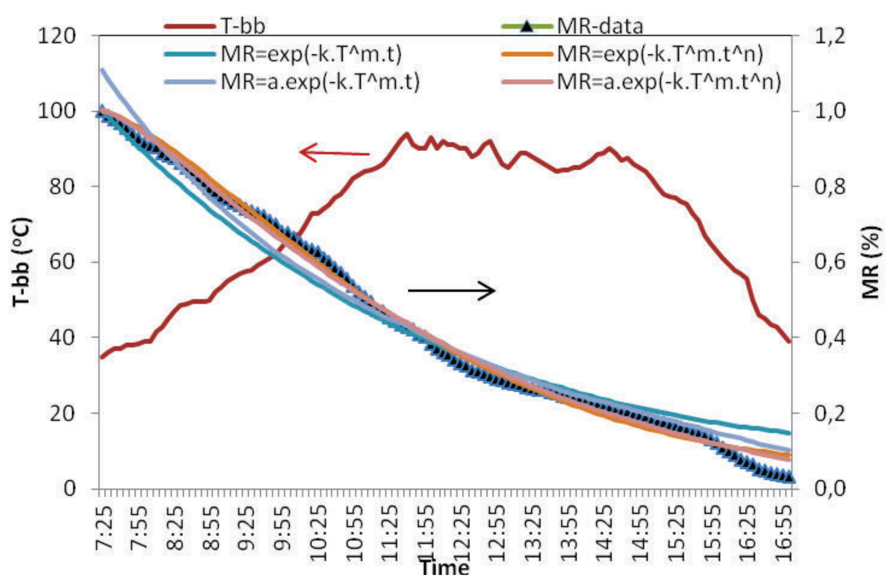


Figure 3. Comparison between experiment and model moisture content or (MR_{exp}) and (MR_{model})

4. Conclusion

So that it can be stated that equation 6 and equality 8 (Equation Page and Henderson and Pabis modified equation with temperature) are match with the drying process with RMSE respectively 0.022226 and 0.020833. Error value can be demonstrated in Figure 3 where the experiment and the model data almost coincide. Thus the second equation (Equation Page modified temperature) which can represent the process of drying of curcuma with a double glass plate collector solar dryer with the: MR = exp $(0.004.T^{0.468}.t1^{.3615})$ with RMSE 0.022226.

Double-plate collector solar dryer is very effective for drying agricultural products (Curcuma xanthorrhiza Roxb). Drying speed is expressed by a reduction in material weight reached 84%..Black body temperature reached a maximum of 92^oC and temperature of the material is low, so the active compound in the curcuma is not damage. Performance dryers plate collector with an area of 0.6 m2, can be for drying of 2 kg curcuma. With the characteristic parameter is expressed by SMER = 0.5881 kg $(kWh)^{-1}$. As for the model equations corresponding to the drying process was modified Page equation with temperature. The equation is expressed as MR = exp $(0.004.T^{0.468}.t^{1.3615})$ with RMSE 0.022226. Applications of this research can improve the quality of products.

Nomenclature

a, b, c, g, h, m,n, k	: empirical constants in drying models	T	: temperature
		$Gs,_0$	: weight of sample at t=0
		$Gs,_t$	: weight of sample at t
N	: number of observations	t,	: time
Me	: moisture content in equilibrium state (dry basis)	N	: number of observations
		Gw	: weight of wet sample
M	: moisture content	Gd	: weight of dry sample
M_0	: moisture content at t = 0 (dry basis)	W	: amount of water that evaporates
M_t	: moisture content at t (dry basis)	Ed	: energy for drying
MR_{exp}	: experimental moisture ratio	SMER	: specific moisture evaporation rate
MR_{pre}	: predicted moisture ratio	a	: area of colector
RMSE	: root mean square error	I	: Sunlight intensity

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